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IS BURNING AN EFFECTIVE MANAGEMENT PRACTICE FOR THE PACIFIC NORTHWEST CEREAL REGION?

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Many cereal producers on the Columbia Plateau burn stubble as a management practice. The reasons offered include disease, insect, and weed control, improved tillage efficiency, reduced immobilization of N fertilizer, and sociological precedents ("The neighbors do it."). However, stubble burning, if used regularly, contributes to erosion and the loss of organic matter. Stubble burning may also produce undesired side effects including increased air pollution, driving hazards, polluted water, and ill will among the urban populations near the burned field. Emerging environmental restrictions are making the practice of burning increasingly difficult.

Burning is a natural part of some ecosystems. Fires in tallgrass prairies occurred frequently, altered nutrient cycling, and temporarily increased primary productivity. Ojima et al., (1994) found that, in the short term, fire in the tallgrass prairie enhanced microbial activity, increased above and below ground plant production, and N use efficiency. Repeated annual burning resulted in a significant reduction in soil organic N, lower microbial biomass and N availability, and increased N immobilization. This response occurred within two years and persisted over the next 50 years of annual burning. Burning forest understory removes flammable biomass that contributes to harmful fires if allowed to accumulate. Uncontrolled fire can cause severe economic and ecosystem damage. Burning grass-seed producing fields can reduce disease incidence and improve crop yield and quality. The effects of fire in these environments is not the same as that in cereal crops in the dryland Pacific Northwest. Cereal production involves much more soil tillage, which alters burning effects and increases susceptibility to wind and water erosion. The closest dryland cereal production can come to either a forest or grass-seed system would be a burn no-till management system. Burning produces different effects in unlike environments, in part due to the intensity of the tillage that follows.

EFFECT ON PESTS

Burning can destroy insects, plant pathogens, and weed seed found in cereal residues and thus reduce their incidence. Unfortunately, the positive effects of burning for reducing pest populations, and thus increasing cereal grain yield, are not always consistent (Hardison, 1976). The high temperatures generated above the stubble during burning are not uniform throughout the canopy. Incomplete destruction of pathogens, insects, or weed seeds at the soil surface will allow their propagation following a fire, thereby producing inconsistent results (Rasmussen, et al. 1986). Rasmussen and Rohde (1988) found that stubble burning did not decrease Strawbreaker foot rot (*Pseudocercosporella herpotrichoides*) incidence or severity, although burning did reduce downy brome (*Bromus tectorum*) density when not effectively controlled by mechanical tillage. It is possible that burning can actually worsen pest problems. Fields blackened by a burn and planted with wheat reflect the long-wave light attractive to aphids (Cook and Veseth, 1991). Stubble burning is rarely necessary where crop rotations offer the same or better control of root diseases, insect pests, and possibly some weeds. Burning may be justified as an emergency treatment, but not as a long-term tool for cereal health management (Cook and Veseth, 1991)

EFFECT ON EROSION

Maintaining residue on the soil surface is effective for controlling soil erosion in the Pacific Northwest. Soils exposed by burning are very susceptible to both wind and water erosion. Nutrients are lost when soil erodes. Repeated burning can alter both physical and chemical properties of soil. The loss of organic matter, coupled with excessive tillage, increases soil compaction and reduces water infiltration and retention. Adverse effects on water infiltration and surface crusting are very difficult to reverse. The negative impact of burning on erosion is difficult to measure; it may not be evident for 10 to 15 years (Pimentel et al., 1995).

EFFECT ON NUTRIENT AVAILABILITY

Many mineral nutrients (e.g. calcium, magnesium, potassium, zinc, copper, and manganese) remain on the soil in the ash following stubble burning. However, the major elements required for plant growth, N and S, are appreciably vaporized during burning (Boerner, 1982). Table 1 shows the volatilization of several elements, based on the burn loss of 65 percent of the stubble biomass.

After carbon, N is the element most affected by fire; a temperature of only 200°C can induce volatilization (Raison, 1979). Data for many ecosystems affected by fire show that, in general, the total soil N content decreases after a fire (Dunn et al., 1979, Raison, 1979). In the Pacific Northwest dryland cereal regions, soils are generally deficient in N and S and their loss through stubble burning has the potential to decrease long-term nutrient availability and increase fertilizer requirements.

Table 1. Volatilization of Elements By Burning.

Element	Initial	Lost	Percent Loss
	- - - -lbs/acre- - -		
Carbon	3570	2320	65
Nitrogen	32.1	11.6	36
Sulfur	5.4	1.4	26
Phosphorus	5.4	0.3	6
Potassium	88.4	4.9	6

Only when residues have a high C to N ratio, will burning increase short-term N and S availability. Burning removes a significant portion of the wheat stubble, thereby reducing carbonaceous material in the soil that serves as the food supply for soil microorganisms. Reduced growth by microorganisms decreases their demand for N and consequently lessens microbial immobilization of N fertilizer in soil (Boerner, 1982).

EFFECT ON BIOLOGICAL ACTIVITY

Information about burning, as it affects soil organic matter, is scarce. Repeated burning can cause gradual loss of organic matter and decreased microbial activity (Biederbeck et al., 1980, Rasmussen et al., 1980). One possible reason for reduced microbial activity is the loss of soil microorganisms during fires. Microbial populations generally recover rapidly with new plant growth. The soil microorganisms are reestablished from underlying soil, wet and dry deposition, or from small islands of unburned residue.

Microbial activity in the soil can be lost or reduced by removal of the food supply. Fire may reduce the most labile organic fractions, leaving only the resistant ones. This decreases soil microbial activity and the amount of N generated by mineralization. As shown in Figure 1, about 80 percent of crop residue in an unburned system is oxidized by the soil microorganisms and lost as carbon dioxide through microbial respiration.

The remaining 20 percent is incorporated into soil organic matter. This material is generally either in microbial biomass, a by-product of microbial metabolism, or in a form that microorganisms cannot easily use.

When stubble is burned, about 60 percent of the crop residue is lost immediately as carbon dioxide or carbon dioxide, and some as carbon monoxide (Figure 2). The remaining 40 percent is eventually incorporated into the soil. If this burned stubble is oxidized by soil microorganisms in the same way as unburned material, then only eight percent (NOT 40 percent) will be converted into soil organic matter.

If soil microorganisms cannot use this material efficiently, the amount that eventually becomes soil organic matter will be even less than eight percent. Burn ash, including the charred C, may not be a possible energy source for microorganisms. Carbon exists in forms (e. g., diamonds) that cannot support microbial growth. If the soil microorganisms cannot derive energy from the burned stubble, regardless of whether it contains C, it cannot contribute to the biological activity of the soil or help form soil organic matter.

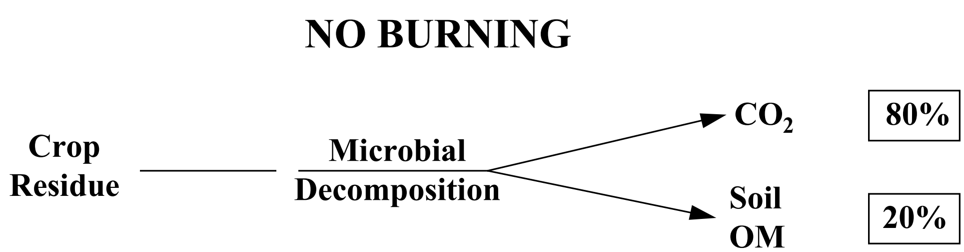

Figure 1. Pathway of C following microbal decomposition. Percentages in boxes represent amount of C partitioned into each end product. OM = organic matter.

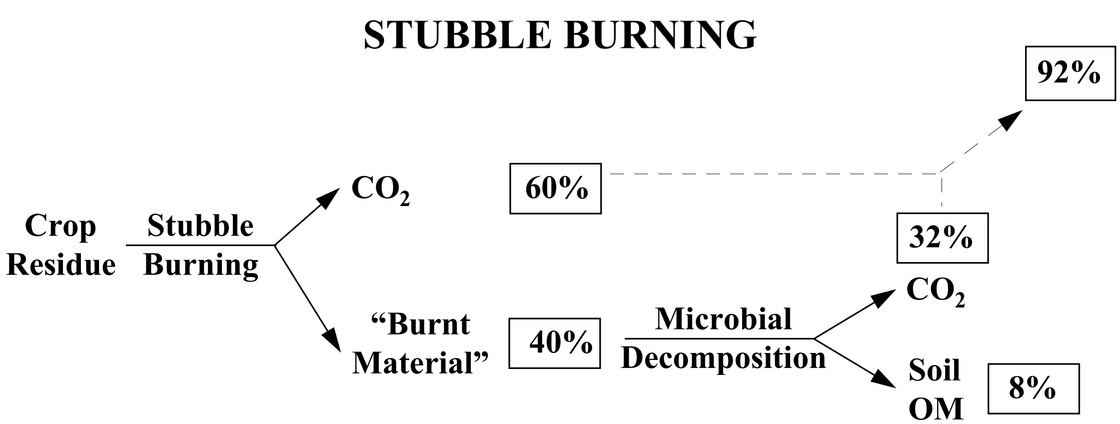

Figure 2. Pathway of C following a fire and microbial decomposition. Percentages in boxes represent amount of C partitioned into each end product. OM = organic matter.

Incubation Tests. Wheat residue or burned wheat stubble was added to an Adkins fine sandy loam soil (Mixed, mesic, Xerollic Camborthid), to determine if microorganisms would utilize the burned stubble as well as the unburned residue. Burned stubble and wheat straw were added to the soil at rates of 7,925 and 4,750 pounds per acre, respectively. Soil samples without residue additions were used as a control. Soils were watered to field capacity and incubated for up to 10 days at 75° F. Nitrate mineralization or immobilization was determined using an ALPKEM rapid flow analyzer and soil biological activity estimated by carbon dioxide respiration using a Beckman infrared gas analyzer. Total C and N were determined using a Fisons carbon-nitrogen analyzer.

The effect of residue addition on biological activity is shown in Table 2. The addition of wheat straw increased the respiration rate of soil microorganisms much more than did the addition of burned stubble. Following the addition of burned stubble, the sustained increase in biological activity was less than seven days, while that for wheat straw residue greatly exceeded 10 days.

Table 2. Change in Biological Activity with Residue Additions. 1994, Pendleton, OR.

Day	Wheat Straw	Burned Stubble
1	80†	29
4	61	9
7	47	0
10	28	0

† Percent increase over control.

The change in nitrate mineralization following the addition of wheat straw and burned stubble is presented in Table 3. After one day the wheat straw had immobilized 71 percent of the nitrate present in soil, while the burned stubble showed a 12 percent increase. After seven days, the addition of wheat straw had completely immobilized all the nitrate, but the burned stubble actually increased mineralization by 24 percent.

Table 3. Change in Nitrate Mineralization Following Residue Additions. 1994, Pendleton, OR

Day	Wheat Straw	Burned Stubble
1	-71†	12
4	-100	24
7	-100	24

† Percent increase or decrease in mineralization when compared to control.

Why did wheat straw quickly immobilize nitrate while burned stubble did not? The carbon added in the burned stubble failed to support microbial respiration. This C appeared to be chemically different from the C in wheat straw and was not available as an energy source for soil organisms. This C in burned material would be detected by all present soil testing laboratory analysis and be reported as "soil organic matter". But, as shown here, the burned stubble is much less biologically active in soil. This strongly suggests that the traditional methods for estimating soil organic matter are inadequate and results must be interpreted cautiously.

EFFECT ON YIELD

Burning has a mixed effect on cereal yield, depending on cropping sequence, disease history, and weed seed intensity. In an annual wheat no-till system, burning increased winter wheat yield about 13 percent and spring wheat three to four percent (Rasmussen, unpublished data). After fallow, winter wheat yields neither increased nor decreased following wheat stubble burning (Rasmussen and Rohde, 1988).

SUMMARY

Stubble burning remains controversial. Although burning is an easy way to quickly prepare grain fields for tillage, there is little evidence burning will consistently control plant diseases, weeds or insects. The loss of soil organic matter favors erosion and may alter nutrient cycling. Fertility is modified immediately after the fire and, more importantly, for the long term. This consequently affects the recovery of the soil and impacts agricultural sustainability. In semiarid regions where drought limits yield, the reduction of organic matter by burning, and subsequent loss of infiltration may eventually be detrimental to cereal yields. In conclusion, when the positive and negative aspects of burning as a management tool are weighed, short-term benefits may often be outweighed by long-standing harm to soil quality.

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